

DOCUMENT RESUME

ED 275 552

SE 047 535

AUTHOR Aikenhead, Glen S.; And Others
TITLE Research Methodologies for Monitoring Student Viewpoints.
INSTITUTION Saskatchewan Univ., Saskatoon. Coll. of Education.
PUB DATE 85
NOTE 31p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (59th, San Francisco, CA, March 28-April 1, 1986).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150) -- Tests/Evaluation Instruments (160)
EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Attitude Measures; *Evaluation Methods; Foreign Countries; Research Needs; *Science and Society; Science Education; Science Instruction; Secondary Education; *Secondary School Science; Social Influences; *Student Attitudes; Technological Advancement; Technology; Validity
IDENTIFIERS *Saskatchewan; *Science Education Research

ABSTRACT

The rationale and the methodology used in a study of high school graduates' viewpoints on science-technology-society (STS) topics are reviewed in this paper. The study employed the instrument, Views on Science-Technology-Society (VOSTS), which required students to write an argumentative paragraph responding to one of 46 statements about an STS topic. The target population consisted of graduating high school students (N=10,800) throughout Canada. Responses from a stratified random sampling were analyzed by three researchers and the response categories were established from students' arguments in the paragraphs. This paper primarily focuses on the instrument's format and validity and the research issues associated with this type of study. Actual results of the study are reported in related papers. Implications of the study are discussed in terms of: (1) strategies to improve understanding of student views on STS topics; (2) research possibilities; and (3) ideas for classroom teachers. Appendices include parts of the student questionnaire and outlines of the topics used in VOSTS. Forty-eight references are included. (ML)

* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *

ED275552

RESEARCH METHODOLOGIES FOR MONITORING STUDENT VIEWPOINTS

Glen S. Aikenhead

And Others

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

X This document has been reproduced as
received from the person or organization
originating it.

☐ Minor changes have been made to improve
reproduction quality.

• Points of view or opinions stated in this docu-
ment do not necessarily represent official
OERI position or policy.

"PERMISSION TO REPRODUCE THIS
MATERIAL HAS BEEN GRANTED BY

Glen S.
Aikenhead

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)."

Paper presented at the Annual Meeting of the National Association for
Research in Science Teaching (59th, San Francisco, CA, March 28 - April 1, 1986).

BEST COPY AVAILABLE

SE 047 535

INTRODUCTION

This paper establishes the rationale and methodology for a study of high school graduates' viewpoints on science-technology-society (STS) topics. Following this paper, the substantive results of the study are reported in a three-part series of papers dealing with: (1) the interaction among science, technology and society (Fleming, 1985), (2) the characteristics and limitations of scientific knowledge (Aikenhead, 1985b), and (3) the characteristics of scientists (Ryan, 1985). These papers document and discuss what students understand about various STS topics. In addition, all three papers raise several research issues. These research issues constitute a second focus to the present paper, and are found in the sections "reflections on instrument validity" and "implications." Therefore, this paper serves two purposes: it describes the research study and it discusses the findings which relate to research issues. The other three papers will present and discuss the substantive results which concern the beliefs students generally hold about STS.

A Curriculum Perspective

Teaching science as a human endeavour has been an emphasis of high school education from time to time during this century (Roberts, 1982). The 1960s saw innovations such as the History of Science Cases (Klopfer, 1966) and Project Physics (Holton, Rutherford & Watson, 1970), both set in a humanistic historical perspective. During the next decade, Science: A Way of Knowing (Aikenhead & Fleming, 1975) and the Studies in Scientific Enquiry project (OISE, 1976) were developed, each with its own approach to the human qualities and social aspects of science.

The 1980s ushered in a number of curriculum projects which present science in its social context, interacting with technology and society. Programs include: Science in Society (Lewis, 1981), Science and Society Teaching Units (Roberts, 1981), Preparing for Tomorrow's World (Iozzi, 1982), the PLON project (Eijkelhof & Kortland, 1982), Science in the Social Context (Solomon, 1983), and Innovations: The Social Consequences of Science and Technology (BSCS, 1984). These projects emerged from the belief that science education was not properly preparing students to function responsibly in a society which is dramatically affected by science and technology (Aikenhead, 1980; Bybee, 1985; Ziman, 1980).

This renewal toward teaching science as a human endeavour, science-technology-society (STS) education, is supported by the National Science Teachers' Association (NSTA, 1982) and the Association for Science Education (ASE, 1979). STS education is a principal recommendation of the Science Council of Canada (1984) and remains the focus of international symposia such as those held in Brisbane, December 1984, and Bangalore, August 1985. While some attention has always been given to teaching the human aspects of science, the STS movement is currently receiving an unprecedented breadth of support.

An Evaluation Perspective

Along with the STS goals and curriculum materials has come the evaluation of student understanding of STS. Standardized instruments were developed in the 1960s to quantify student understanding: Test on Understanding Science, TOUS (Cooley & Klopfer, 1961), Nature of Science Scale, NOSS (Kimball, 1965), Science Process Inventory, SPI (Welch, 1966), and the Test of the Social Aspects of Science, TSAS (Korth, 1968). The validity of these instruments

essentially rested on theoretical positions within the philosophy of science (Lucas, 1975). The instruments were reviewed by Aikenhead (1973) who pointed out the advantages of using qualitative data, instead of quantitative data, as feedback for monitoring student conceptions and misconceptions. Various researchers around the world have used these standardized instruments to establish baseline data of student understanding about various aspects of STS; for example, Korth (1969) in the USA, MacKay (1971) in Australia, Tamir (1972) in Israel, and Aikenhead (1975) in Canada. The National Assessment of Educational Progress (NAEP) constructed its own STS items for its 1972, 1976 and 1981 surveys in the USA (Bybee, Harms, Ward & Yager, 1980; Hueftle, Rakow & Welch, 1983). Such survey data tend to guide policy makers and curriculum developers.

It is beyond the scope of this study to explore the problematic area of student attitudes (Gardner, 1975; Hukins, 1980; Munby, 1983). Consequently, evaluation instruments which stress affect over conceptual understanding--the distinction can often be extremely fuzzy--are not mentioned here.

In Canada, the Science Council of Canada's education study was able to survey science teachers' views on STS goals (Orpwood & Alam, 1984) but because the Council's federal status was perceived as interfering with the provinces' jurisdiction over education, the study was unable to assess student understanding of STS topics. This missing information is an obstacle to knowing what is currently being achieved by science education in the area of STS, and is a deficiency for teachers and curriculum developers who wish to design STS lessons and materials. Teachers and curriculum specialists need to know what STS concepts students generally believe in before instruction can be designed and offered to these students.

In 1983, the Second International Science Study of the International

Association for the Evaluation of Educational Assessment (IEA) initiated a student evaluation project in Canada (Connelly, Crocker & Kass, 1984). It became possible to assess Canadian students' understanding of STS topics by surveying a large national sample.

Purposes of the Study

The purposes of this study were (1) to monitor student understanding of STS topics using a large national sample of graduating high school students; and (2) to do this in a manner that improves upon similar research projects mentioned above and in a way that could lead to a new generation of standardized instruments that would describe viewpoints on STS topics.

NATIONAL SAMPLE

The sampling for this study was carried-out by the Canadian IEA study (Connelly, Crocker & Kass, 1984). Because of the administrative difficulty of selecting a national student sample based strictly on a student's graduating status in high school (grade 13 for Ontario schools, grade 12 for other schools in this study), the sample was selected mostly on the basis of course registration. The target population comprised students taking the second year offering of biology, chemistry or physics, plus students in their final year of high school who were not taking any science courses at all. Canadian students finishing a second year level of biology, chemistry or physics are roughly equivalent to 12th grade American students finishing a first year science course. Canadian students take nine or 10 courses per year compared with the five-course load of the average American student. Thus the typical American science course is taught over a two-year period in Canada, usually in

the last two years of high school.

For administrative purposes, Canada was partitioned by the IEA study into three regions: west (British Columbia, Alberta, Saskatchewan and Manitoba), central (Ontario), and Atlantic (Newfoundland, Prince Edward Island, Nova Scotia and New Brunswick). The population of graduating students numbered about 202,000 and were enrolled in 1,941 schools across Canada, excluding Quebec, the Yukon and Northwest Territories. A stratified sample was selected in each of the three regions, yielding about 10,800 students in total and comprising approximately 5% of the target population.

In May and June 1984, a questionnaire was filled out by all students in the sample; 3,748 were from the west (35%), 4,612 were from central Canada (43%), and 2,440 were from the Atlantic region (22%). The present study is an in-depth analysis of one page of this questionnaire, a page that asked students to write an argumentative paragraph. All other items in the questionnaire were machine scored.

From this one page of the questionnaire, the following demographic data were gleaned. There was an equal number of males and females in the sample. Ages ranged from 14 to 27, with 99% falling in the 16 to 20 age bracket, giving a mean age of 17.6 years (5% were 16, 34% were 17, 44% were 18, 14% were 19, and 2% were 20). Most students (41%) were taking two sciences at the time they wrote the questionnaire, 37% were studying one science, 14% were enrolled in all three sciences, and 8% were not studying science at all.

THE STS INSTRUMENT

Design Format

The evaluation instruments TOUS, NOSS, SPI and TSAS have one feature in

common: they use objectively scored items. Some instruments force students to agree or disagree, while others allow for a wider response; for example, strongly agree, do not understand, do not know, and strongly disagree. But in all cases, the tests harbour the implicit assumption that both the student and the researcher perceive the same meaning in the item. Munby (1982, p. 207) referred to this assumption as "the doctrine of immaculate perception." When students process and respond to an objectively scored item, they subjectively make their own meaning out of the item. The standardized tests may be objective to the scorer, but they turn out to be quite subjective to the student. By shifting the responsibility for handling subjectivity to the mature adult researcher, one can discern diversity and insight "objectively" described by students. This study attempted to do exactly that.

Instead of employing a Likert-type scale normally found in standardized instruments, this study developed an instrument which requires students to write an argumentative response--a reaction to a statement about a STS topic. Rather than analyzing "right" and "wrong" answers, we let the students' arguments define various positions or viewpoints on each STS topic.

Specifically, a single sheet (shown in Appendix A) was inserted into the student's questionnaire. The space under "Statement" on the sheet contained one of 46 statements; number 1.1 is found as an illustrative example in Appendix A. These statements constitute the content of the STS instrument. Students were asked to agree or disagree with the statement, or say they "can't tell," in order to establish a particular position from which they could explicitly argue.

Content and Development

The content of the earlier standardized tests listed above is firmly

rooted in theoretical models from the philosophy of science. While our instrument continues to reflect the epistemology of science represented in these theoretical models, it also draws upon investigations in the social context of science which have given additional perspectives on STS (Aikenhead, 1985; Gauld, 1982)--views traditionally ignored in the philosophy of science literature. Some examples include: the role of women in science, the communication of scientists with the general public, scientists and values, the effect of social interactions on knowledge discovered, and socioscientific decision making.

The STS topics included for consideration were those emphasizing cognition over attitude. Our study monitored the reasons that students gave to justify their opinions. Student agreement or disagreement with a statement was solicited in order to establish an opinion (from which attitudes may be inferred, Bybee, Harms, Ward & Yager, 1980); but in justifying their opinions, students shifted their attention away from their attitudes towards their cognition. Examples of cognition include: what scientists do when they do science, why women are not better represented in science, or the interdependence/independence of science and government. Consideration was not given to students' feelings about global or regional issues. The present study concentrated on informed opinions by eliciting the reasons that students thought were informing their opinions. These reasons tend to rely on conceptual knowledge--misconceptions included. This conceptual knowledge defines, cognitively, how a student views a STS topic. In this sense, therefore, student understanding of STS topics was monitored by our instrument.

The development of an STS instrument began with certain items being selected from the NOSS, SPI and TSAS in an attempt to encompass their

philosophical models. (The TOUS was not used because its multiple choice format did not lend itself to our desired format and because much of its content is addressed in the other instruments.) These selected items tended to be the ones that students have found to be most clear. The researchers' familiarity with students' responses to many of these statements allowed the researchers to rephrase items in order to enhance their clarity. The statements were also set in a Canadian context.

Certain STS topics were notably absent from this initial set of items. Statements were written to begin to fill in these gaps. No attempt was made to be totally inclusive, however. There is room for future expansion and modification.

For every statement, a converse statement was written, a procedure suggested by Moore and Sutman (1970). In some cases this simply meant casting the statement in the negative. In other cases it meant composing the opposite view; for example, if a democratic view on decision making was found in the initial statement, a technocratic view was written (items 1.1 and 1.2 in Appendix B). In still other cases, several views needed to be expressed; for instance, for the items probing the main motivation of scientists three were written (18.1, 18.2 and 18.3): financial gain, recognition, and satisfying curiosity. Another example would be items 19.1, 19.2 and 19.3 which deal with the role of facts, moral values and personal motives, respectively, in socioscientific decision making.

A polished version of the instrument was field tested locally. Student responses were analyzed to assess the clarity of the instrument's statements and to determine whether students perceived the distinctions and nuances designed into some statements. A revised version, Views on Science-Technology-Society (VOSTS) form CDN-2, contains 46 statements built

around 22 "questions" which address 16 STS topics. A conceptual outline of these 16 topics and their associated questions is shown in Appendix B. This outline is only a heuristic structure that guided the researchers in the formative stages of the study. The 16 STS topics tend to overlap and therefore play havoc with the imposed organizing themes. A listing of the 46 statements is found in Appendix C.

Again, it must be emphasized that the Views on STS (VOSTS) form CDN-2 does not pretend to encompass all the important aspects to STS education. It is open to further development; for example, expanding on such topics as: (1) politics and science, specifically the new alliance between university labs and industry (Dickson, 1984); (2) science policy; and (3) technology, specifically topics of design, resources, management and purpose.

DATA ANALYSIS

Sampling the Responses

A file of responses was organized for each of the 46 statements. Each file contained about 236 responses. There were 10,800 responses in total, too many to analyze in a reasonable length of time. A 30% random sample, stratified for regional representation, was drawn from each of the files. The figure 30% was chosen with the expectation that 70 paragraphs would be a sufficient number to ensure "theoretical saturation" for the categories that would emerge (Glaser & Strauss, 1967).

Saturation means that no additional data are being found whereby the sociologist can develop properties of the category. As he sees similar instances over and over again, the researcher becomes empirically confident that a category is saturated. He goes out of

his way to look for groups that stretch diversity of data as far as possible, just to make certain that saturation is based on the widest possible range of data on the category. (Glaser & Strauss, 1967, p. 61)

If more paragraphs were required to attain saturation, a random sample larger than 30% was used, as was the case for items 18, 19 and 21, for example. In most cases, a 30% sampling easily ensured theoretical saturation and a stable representation of student viewpoints.

Analyzing the Responses

The 46 files of sampled responses were divided among three researchers and analyzed. Initially, the analysis of student responses involved examining both their overall reaction to the VOSTS statement (expressed by checking "agree," "disagree," "can't tell") and their justification (argumentative paragraph).

It quickly became apparent, however, that a student's overall reaction was severely limited and open to misunderstanding. For some items, an equal number of students agreed and disagreed with a VOSTS statement but at the same time offered a similar justification; for example, student position D of 18.1. The agree/disagree/can't tell format did not allow the researcher to adequately determine student reasoning.

The central focus of the analysis, then, became the student paragraphs and how students conceptualized the VOSTS statements. For each paragraph, the researcher wrote a phrase that summarized the student's conceptual viewpoint. When a student expressed more than one position, the first one or the one indicated as most important, was used. After the synoptic paraphrasing was completed, the researcher examined the collection of summary phrases to

discern common arguments. These became "Student Positions." In summary, for each VOSTS statement several student positions were teased out of the data by creating categories paraphrasing common arguments.

Two other types of categories were used, "unique responses" and "not usable responses." The latter included those student response sheets on which (1) no arguments were written (perhaps the student did not have enough time to finish the questionnaire, did not understand, did not have sufficient knowledge, or perhaps did not care), (2) the original statement was simply repeated, or (3) the argument had nothing to do with the statement.

"Unique responses," on the other hand, were those which pertained to the statement but offered a singular argument lying outside the form and/or content of all other arguments presented.

To establish a closeness of fit between the "Student Positions" and the students' original paragraphs, a cross-check was performed by one of the other researchers. All suggested changes were discussed. Most were editorial in nature, designed to increase the clarity of the paraphrased student positions.

The reliability of the categorizing was assessed by randomly selecting a subsample of 30% of the student responses and having them recoded by the researchers. Interjudge reliability (Miles & Huberman, 1984) ranged from 68 to 94% with a mean of 84% agreement.

The results of this analysis are reported and discussed in the three ensuing papers of this paper set (Aikenhead, 1985b; Fleming, 1985; Ryan, 1985). One purpose of the present paper is to report on the research issues that emerge from these three papers. The study's results, discussed in the three papers, raise concerns over the validity of traditional research instruments which have been used to monitor student viewpoints. The results of the study also suggest three types of implications: (1) research

strategies to improve our understanding of students' views on STS topics, (2) significant research that grows out of the present study, and (3) ideas for classroom teachers. These research issues and implications are discussed in turn below.

REFLECTIONS ON INSTRUMENT VALIDITY

Responses as Artifacts of the Item's Wording

The wording of test items is a never ending concern to test designers. Certain words trigger specific, unanticipated reactions from students. The word "accurate" in statement 13.2, for example, encouraged some students to focus on the degree of accuracy of scientific models, thereby missing the intended topic concerning the epistemology of scientific models. "Political climate" in item 10 was misread as geographical climate by a group of respondents. Precise terms or specific examples are often used in an item in an attempt to clarify meaning. (For example, in statement 18.3, scientists' "personal motives" were defined by the examples: "pleasing their employers or wanting grants from the government"). Clarity should reduce misunderstandings, but there are trade-offs. On the one hand, specificity runs the risk of leading students to respond in unidirectional, unwanted ways, but on the other hand, generality runs the risk of superficiality and amorphous student responses. These trade-offs threaten an instrument's validity.

Doctrine of Immaculate Perception

The specificity/generality problem reflects the imprecision of the English language itself, particularly the imprecise way it is read and

interpreted by students. In responding to the VOSTS statements, students formulated arguments drawing upon such common terms as scientific method, scientific fact, tentative scientific knowledge, scientific research, and science and technology; but students used each term in diverse and often contradictory ways. Had the VOSTS been objectively scored, relying on the agree/disagree responses by students, one could easily see the "doctrine of immaculate perception" in operation: thinking that students perceive a statement in the same way as the evaluator does, and therefore assuming that students would agree or disagree with a statement for the same reasons as the evaluator would agree or disagree. For example, evaluators would agree with statement 13.1 (that scientific models do not duplicate reality) because of the evaluators' belief in the metaphoric status of scientific models. However, analysis of student paragraphs revealed two distinct reasons for their agreement, reasons that differed from the evaluators' belief: pragmatic heuristics ("models make it easier to learn"), and historical precedence ("models have changed in the past, and so will change in the future").

Checked Responses Versus Written Responses

The "agree," "disagree," or "can't tell" responses give the evaluator little guidance in understanding student viewpoints. Two examples illustrate this problem. Student position B for statement 13.1 showed 16% of the students arguing in favour of the changeable nature of models. But of this 16%, only half had agreed with the statement. The other half had either disagreed or said they could not tell. Similarly for item 21 (the underrepresentation of women in science), the results show students offering similar arguments in spite of the fact that an equal proportion of these students had agreed and disagreed with statement 21.1. Moreover, 50%, 25% and

25% agreed, disagreed and could not tell, respectively, with the idea that the misrepresentation of women in science was justifiable (statement 21.1). One might infer that 25% felt that the underrepresentation was not justifiable. The data show this inference to be naive. We discovered that 50% agreed with the negative wording of the same statement, that the misrepresentation was not justifiable (statement 21.1). Knowing whether or not students agreed or disagreed gives ambiguous information at best. The VOSTS paraphrases of common student arguments suggest reasons for the students' beliefs, rather than leaving these reasons open to the speculations of evaluators and their "objective" data.

The English language does not necessarily become perfectly precise in the hands of students. Their paragraphs leave some room for interpretation as well. In order to clarify student views further, one would have to probe their beliefs by other techniques (discussed below in "implications").

The Role of Persuasion

For some VOSTS statements (items 11, 16, 18 and 19, for example), students appeared to be swayed by the message conveyed by the statement. Such persuasion occurred more often when a large proportion of student responses were categorized as "not usable;" that is, no paragraphs were written at all, or paragraphs were off the topic. Perhaps these students thought the statement was vague or complex. Greater specificity in wording may reduce this vagueness or complexity, and thus reduce the statement's persuasive quality. On the other hand, increased specificity can trigger unanticipated student responses.

Conversely, in some cases the statement's content had an inverse effect on student responses. For instance, to the claim that social contacts have no

effect on the knowledge discovered by a scientist (statement 17.2), students reacted by emphasizing how social contacts did have an effect on what knowledge was discovered.

Content Validity

Not only is validity challenged by the imprecision and persuasiveness of the English language, but the content validity of VOSTS--STS topics--is hampered by its conceptual immaturity. What is STS? Revisions of the VOSTS have the potential of addressing this question, but first there must be more consensus among the science education community regarding the legitimate domain of STS content. Ziman (1980), McKenzie (1984) and the present study can serve as points of departure for comprehensively delineating STS topics, and thereby establishing content validity for STS evaluation instruments.

Summary

The precision of communication (the closeness of fit) between a student's paragraph and a VOSTS "student position" is much greater than the precision between a student's paragraph and his or her "agree" or "disagree" response. If one objectively scored the VOSTS responses, one would sacrifice precision on the altar of quantitative methodology. Researchers who naively rely on students' Likert-type responses to, say, the Science Attitude Inventory (Moore & Sutman, 1970), the Science Process Inventory (Welch, 1966), or the Nature of Scientific Knowledge Scale (Rubba, 1976), run the risk of exemplifying the doctrine of immaculate perception. The validity of such instruments is challenged by the results obtained from analyzing paragraph responses to the VOSTS form CDN-2.

IMPLICATIONS

Improving the Understanding of Student Viewpoints

Student paragraphs written in response to VOSTS do not necessarily convey the full range of information that a researcher or curriculum developer requires. Greater clarification and amplification may be needed from students; for example: "What is scientific research? What is the scientific method? Why do the words "science" and "technology" seem to be interchangeable? Where do scientists work? How does this information concerning the work place interact with student viewpoints on what scientists do or should do?

In addition to matters of clarification, we need to know more precisely where students' ideas come from (which textbooks, which teachers, which mass media, or which museum).

Furthermore, the responses to VOSTS do not give one a clear idea of how firmly students hold various beliefs.

These three deficiencies in VOSTS (What do students mean more precisely? How do their ideas develop? How resistant are those ideas to further change?) may be overcome by employing a structured interview technique, a powerful research tool that has already been used in STS education research (Fleming, 1984). Local studies, carried out in depth, could richly colour national norms generated by VOSTS, and thereby improve our understanding of student viewpoints on STS topics.

Our understanding of student viewpoints could also be improved by expanding the content addressed by VOSTS form CDN-2. Suggestions include: science in industry and the military, the role of values in the conduct of science, science policy, and technology--its management and resources. Thus,

other researchers may wish to generate new, expanded forms of the VOSTS.

Further Study

Although analyzing student paragraphs yields a wealth of data, it is also very time consuming. Objectively scored methods reduce this time expenditure, but at the expense of not discovering what students really mean and at the risk of generating artifacts. A compromise solution to this problem is suggested as the next logical step for further research. The paraphrases of common student arguments ("student positions") reflect the language used by students. A multiple-choice format for VOSTS is possible, therefore, by using the student positions as choices. A multiple-choice format would enable students to express their views by checking which position(s) they agree with. The fact that the wording itself originally came from a large national sample of students might reduce the "immaculate perception" problem.

International collaboration in testing students, either with paragraph responses or with multiple-choice responses, would allow for cross cultural comparisons. STS educators could better understand students' perceptions of science and technology in the context of different cultures. In Canada, for instance, we look forward to a study in Quebec, because at present, we do not know the extent to which students' views on science-technology-society topics vary between an anglophone and francophone North American culture. Comparisons between highly industrialized and less industrialized nations promise fascinating results.

It would be significant to know the various viewpoints that science teachers hold on these topics, and to be able to compare their positions with those of social studies teachers, university science professors and teacher educators.

Another area for further study concerns the application of the VOSTS results by STS curriculum developers. The VOSTS results document the commonsense conceptions or alternative frameworks ("misconceptions" to some science educators) that students hold prior to STS instruction. The data can inform decisions made by curriculum specialists. As well, VOSTS could serve as yet another source of feedback for the evaluation of STS curriculum materials.

Other projects are possible with the data already collected during the present study; for instance, the effect of gender, the effect of the number of science classes attended at the time of the survey (zero to three), and the effect of regional variations within Canada.

Teachers

VOSTS is of interest to teachers who embrace the idea of including STS topics in their lessons. The findings enable a teacher (1) to compare his or her own position with respect to the positions held by students, (2) to become more sensitive to student viewpoints that he or she had little cognizance of, and therefore (3) to give more attention in the classroom to topics about which students seem naive or ill-informed. The data also serve as a baseline against which teachers might assess how closely student understanding conforms with STS goals stated by such organizations as the National Science Teachers' Association (NSTS, 1982).

REFERENCES

- Aikenhead, G. S. (1973). The measurement of high school students' knowledge about science and scientists. Science Education, 57(4), 539-549.
- Aikenhead, G. S. (1975). Learning about the scientific enterprise in Saskatchewan high school chemistry classes: An evaluation. Saskatchewan Journal of Educational Research and Development, 5(2), 4-29.
- Aikenhead, G. S. (1980). Science in social issues: Implications for teaching. Ottawa: Science Council of Canada.
- Aikenhead, G. S. (1985). Collective decision making in the social context of science. Science Education, 69(3). (in press)
- Aikenhead, G. S. (1985b, April). High school graduates' viewpoints on the characteristics and limitations of scientific knowledge. A paper presented to the 58th annual meeting of the National Association for Research in Science Teaching, French Lick Springs, Indiana.
- Aikenhead, G. S., & Fleming, R. W. (1975). Science: A way of knowing. Saskatoon, Sask.: Department of Curriculum Studies, University of Saskatchewan.
- ASE. (1979). Alternatives for science education. Hatfield, Herts. U.K.: The Association for Science Education.
- BSCS. (1984). Innovations: The social consequences of science and technology. Dubuque, IA: Kendall/Hunt.
- Bybee, R. W. (Ed.). (1985). Science-technology-society. 1985 NSTA Yearbook. Washington, DC: National Science Teachers' Association.
- Bybee, R. W., Harms, N., Ward, B., & Yager, R. (1980). Science, society, and science education. Science Education, 64(3), 377-395.
- Connelly, F. M., Crocker, R., & Kass, H. (1984). A case study of science curriculum in Canada. Vol. VII. Toronto, Ont.: Ontario Institute for Studies in Education.
- Cooley, W. W., & Klopfer, L. (1961). Test on understanding science: form W. Princeton, NJ: Educational Testing Service.
- Dickson, D. (1984). The new politics of science. New York: Pantheon Books.
- Eijkelhof, H., & Kortland, K. (1982, July). The context of physics education. A paper presented at the Second International Symposium on World Trends in Science Education, Nottingham, U.K.
- Eijkelhof, H., Boeker, E., Raat, H., & Wijnbeek, N. (1981). Physics in society. Amsterdam: VU Boekhandel/Uitgeverij.

- Fleming, R. W. (1984). Social and non-social cognitive structures in decision making in socio-scientific issues: Implications for science-technology-society curricula. Unpublished doctoral dissertation, University of California at Berkeley.
- Fleming, R. W. (1985, April). High school graduates' viewpoints on the interaction among science, technology and society. A paper presented to the 58th annual meeting of the National Association for Research in Science Teaching, French Lick Springs, Indiana.
- Gardner, P. L. (1975). Attitudes to science: A review. Studies in Science Education, 2, 1-41.
- Gauld, C. (1982). The scientific attitude and science education: A critical reappraisal. Science Education, 66(1), 109-121.
- Gauld, C., & Hukins, A. (1980). Scientific attitudes: A review. Studies in Science Education, 7, 129-161.
- Glaser, B. G., & Strauss, A. L. (1967). The discovery of grounded theory: Strategies for qualitative research. Chicago: Aldine Publishing.
- Holton, G., Rutherford, J., & Watson, F. (1970). Project physics. New York: Holt, Rinehart and Winston.
- Hueftle, S. J., Rakow, S. J., & Welch, W. W. (1983). Images of science. Minneapolis, MN: Minnesota Research and Evaluation Center, University of Minnesota.
- Kimball, M. E. (1965). Opinions of scientists and science teachers about science. Unpublished doctoral dissertation, Stanford University.
- Klopfer, L. (1966). History of science case studies. (A series of six cases). Chicago: Science Research Associates Inc.
- Korth, W. W. (1968). The use of the history of science to promote student understanding of the social aspects of science. Unpublished doctoral dissertation, Stanford University.
- Korth, W. W. (1969). Test every senior project: Understanding the social aspects of science. Cleveland: Educational Research Council of America. (ERC papers in Science Education #4)
- Iozzi, L. A. (Project Director). (1982). Preparing for tomorrow's world. (A series of modules). Rutgers, NJ: The State University of New Jersey New Brunswick.
- Lewis, J. (Project Director). (1981). Science in society. London: Heinemann Educational Books.
- Lowe, I. (1984, December). Some important examples of the STS interaction. A paper presented to the Third International Symposium on World Trends in Science Education, Brisbane, Australia.

- Lucas, A. M. (1975). Hidden assumptions in measures of 'knowledge about science and scientists.' Science Education, 59(4), 481-485.
- Mackay, L. D. (1971). The development of understanding about the nature of science. Journal of Research in Science Teaching, 8(1), 57-66.
- Mckenzie, S. (1984, December). A framework for teaching STS. A paper presented to the Third International Symposium on World Trends in Science Education, Brisbane, Australia.
- Miles, M. B., & Huberman, A. M. (1984). Qualitative data analysis. Beverly Hills, CA: Sage.
- Moore, R. W., Sutman, F. X. (1970). The development, field test and validation of an inventory of scientific attitudes. Journal of Research in Science Teaching, 7, 85-94.
- Munby, H. (1982). The place of teachers' beliefs in research on teacher thinking and decision making, and an alternative methodology. Instructional Science, 11, 201-225.
- Munby, H. (1983). Thirty studies involving the "Scientific Attitude Inventory:" What confidence can we have in this instrument? Journal of Research in Science Teaching, 20(2), 141-162.
- OISE (Patterns of Enquiry Project Staff). (1976). Studies in scientific enquiry. (A series of modules). Toronto: Ontario Institute for Studies in Education.
- Orpwood, G. W., & Alam, I. (1984). Science education in Canadian schools. Vol. II. Ottawa: Science Council of Canada.
- Roberts, D. A. (Ed.). (1981). Science and society teaching units. (A series of modules). Toronto: Ontario Institute for Studies in Education.
- Roberts, D. A. (1982). Developing the concept of "curriculum emphases" in science education. Science Education, 66(2), 243-260.
- Rubba, P. A. (1976). Nature of scientific knowledge scale. Bloomington, IN: School of Education, Indiana University.
- Ryan, A. G. (1985, April). High school graduates' viewpoints on the characteristics of scientists. A paper presented to the 58th annual meeting of the National Association for Research in Science Teaching, French Lick Springs, Indiana.
- Science Council of Canada. (1984). Science for every student: Educating Canadians for tomorrow's world. Ottawa: Science Council of Canada.
- Solomon, J. (1983). Science in a social context (SISCON) in schools. Oxford: Basil Blackwell.

Tamir, P. (1972). Understanding the processes of science by students exposed to different science curricula in Israel. Journal of Research in Science Teaching, 9(3), 239-245.

Welch, W. W. (1966). Welch science process inventory, form D. Minneapolis, MN: Minnesota Research and Evaluation Center, University of Minnesota.

Ziman, J. (1980). Teaching and learning about science and society. Cambridge: Cambridge University Press.

APPENDIX A

STUDENT QUESTIONNAIRE SECTION 4

As soon as you have finished the questions in Booklet 1, please read the following instructions. All of Section 4 is done on this sheet.

BACKGROUND INFORMATION

Code: _____ Age: _____ Male _____ Female _____

Which sciences are you presently studying?

____ biology ____ chemistry ____ physics ____ none of these

WHAT'S IT ALL ABOUT?

We want to understand the viewpoints that high school students hold on the complex topic "science, technology and Canadian society". There are about 45 statements covering this topic. We would like to know your viewpoints on ONE of these statements (the one printed below). Each person in your class has a different statement to write about. Thank you for sharing your viewpoint with us.

INSTRUCTION TO STUDENTS

Please state whether you agree or disagree with the following statement. Then briefly explain your reasons for agreeing or for disagreeing. Two to four sentences should be enough to make your reasons clear. If you cannot agree or disagree, then explain why a choice is not possible for you.

STATEMENT

- 1.1 Scientists and engineers should be given the authority to decide what types of energy Canada will use in the future (e.g. nuclear, hydro, solar, coal burning, etc.) because scientists and engineers are the people who know the facts best.

Response: (check one) ____ agree ____ disagree ____ can't tell

Reasons:

(Use the reverse side, if you need more space.)

APPENDIX B

Heuristic Outline of Topics in Views on STS form CDN-2

	<u>Question #</u>
I. THE INTERACTION OF SCIENCE, TECHNOLOGY & SOCIETY	
A. <u>The Influence of Science/Technology on Society</u>	
1. The technocratic & democratic views on socio-scientific decision making.	1
2. The social responsibility of scientists.	2,3,4,5
3. The role of science and technology in resolving social problems.	6
B. <u>The Influence of Society on Science/Technology</u>	
1. Public influence on the direction of science.	7,8
2. Government control of science.	9,10
C. <u>Science and Technology</u>	
1. The interdependence of science and technology.	11
2. The distinction and relationship between science and technology.	12
II. CHARACTERISTICS OF SCIENTIFIC KNOWLEDGE	
1. The nature of scientific models.	13
2. The nature of classification schemes.	14
3. The tentativeness of scientific knowledge.	15
4. The nature of a scientific approach to knowledge.	16
5. The social nature of scientific knowledge.	17,18
6. The main motivation for generating scientific knowledge.	19
III. CHARACTERISTICS OF SCIENTISTS	
1. The human character of scientists.	20
2. The underrepresentation of females among scientists.	21
3. The honesty and objectivity of scientists.	22

APPENDIX C

Views on Science-Technology-Society form CDN-2

Developed by
 Glen Aikenhead, Reg Fleming, Alan Ryan
 College of Education, University of Saskatchewan
 February 1984

I. THE INTERACTION OF SCIENCE, TECHNOLOGY & SOCIETY

A. The Influence of Science/Technology on Society:

- 1.1 Scientists and engineers should be given the authority to decide what types of energy Canada will use in the future (e.g. nuclear, hydro, solar, coal burning, etc.) because scientists and engineers are the people who know the facts best.
- 1.2 Scientists and engineers should be the last people to be given the authority to decide what types of energy Canada will use in the future (e.g. nuclear, hydro, solar, coal burning, etc.). Because the decision affects everyone in Canada, the public should be the ones to decide.
- 2.1 Most Canadian scientists are concerned with the potential effects (both helpful and harmful) that might result from their discoveries.
- 2.2 Most Canadian scientists are not concerned with the potential effects (both helpful and harmful) that might result from their discoveries.
- 3.1 Canadian scientists should be concerned with the potential effects (both helpful and harmful) that might result from their discoveries.
- 3.2 Canadian scientists should not be concerned with the potential effects (both helpful and harmful) that might result from their discoveries.
- 4.1 Canadian scientists should be held responsible for harm that might result from their discoveries.
- 4.2 Canadian scientists should not have to be responsible for harm that might result from their discoveries.
- 5.1 Canadian scientists should be held responsible for reporting their findings to the general public in a manner that the average Canadian can understand.

5.2 Canadian scientists should not have to feel responsible for reporting their findings to the general public in a manner that the average Canadian can understand.

6.1 Although advances in science and technology may improve living conditions in Canada and around the world, science and technology offer little help in resolving such social problems as poverty, crime, unemployment, overpopulation and the threat of nuclear war.

6.2 Science and technology offer a great deal of help in resolving such problems as poverty, crime, unemployment, overpopulation and the threat of nuclear war.

B. The Influence of Society on Science/Technology:

7.1 The Canadian government should give scientists research money only if the scientists can show that their research will improve the quality of living in Canada today.

7.2 The Canadian government should give scientists research money to explore the unknowns of nature and the universe.

8.1 Communities or government agencies should not tell scientists what problems to investigate because scientists themselves are the best judges of what needs to be investigated.

8.2 Communities or government agencies should tell scientists what problems to investigate; otherwise scientists will investigate only what is of interest to them and not necessarily investigate the problems of interest to communities or government agencies.

9.1 Science would advance more efficiently in Canada if it were more closely controlled by our government.

9.2 Science would advance more efficiently in Canada if it were independent of government influence.

10.1 The political climate of Canada has little effect upon Canadian scientists because they are pretty much isolated from Canadian society.

10.2 The political climate of Canada affects Canadian scientists because they are an integral part of Canadian society.

C. Science and Technology:

- 11.1 In Canada, science and technology have little to do with each other.
- 11.2 In Canada, technology gets ideas from science and science gets new processes and instruments from technology.
- 12 In order to improve the quality of living in Canada, it would be better to invest money in technological research rather than scientific research.

II. CHARACTERISTICS OF SCIENTIFIC KNOWLEDGE

- 13.1 Many scientific models (such as a model of the atom or of DNA) are metaphors or useful stories; we should not believe that these models are duplicates of reality.
- 13.2 Many scientific models (such as a model of the atom or of DNA) are accurate duplicates of reality.
- 14.1 When scientists classify something (e.g. a plant according to its species, an element according to the periodic table, or energy according to its source), scientists are classifying nature according to the way nature really is; any other way would simply be wrong.
- 14.2 When scientists classify something (e.g. a plant according to its species, an element according to the periodic table, or energy according to its source), scientists are classifying nature according to a scheme which was originally created by other scientists; thus there could be many correct ways of classifying nature.
- 15.1 When scientific investigations are done correctly, scientists discover knowledge that will not change in future years.
- 15.2 Even when scientific investigations are done correctly, the knowledge that scientists discover may change in the future.

- 16.1 The best scientists are those who follow the steps of the scientific method.
- 16.2 The best scientists are those who do not lock themselves into following the steps of the scientific method, but instead use any approach that might help them.
- 17.1 A scientist may play tennis, go to parties, or attend conferences with other scientists or with non-scientists. Because these social contacts can influence the scientist's work, these social contacts can influence the content of the scientific knowledge he or she discovers.
- 17.2 Although a scientist may play tennis, go to parties, or attend conferences with other scientists or with non-scientists, these social contacts do not influence the scientist's work, and therefore these social contacts have no effect on the content of the scientific knowledge he or she discovers.
- 18.1 When scientists disagree on an issue (e.g. whether or not low-level radiation is harmful), they disagree mostly because one side does not have all the facts.
- 18.2 When scientists disagree on an issue (e.g. whether or not low-level radiation is harmful), they disagree mostly because of their different moral values.
- 18.3 When scientists disagree on an issue (e.g. whether or not low-level radiation is harmful), they disagree mostly because of their different personal motives (e.g. pleasing their employers or wanting research grants from the government).
- 19.1 Earning a decent salary is really the main motivation of most Canadian scientists.
- 19.2 Earning recognition from other scientists is really the main motivation of most Canadian scientists.
- 19.3 While earning recognition is important to Canadian scientists, the most important thing is for them to satisfy their curiosity about natural phenomena.

III. CHARACTERISTICS OF SCIENTISTS

- 20.1 Scientists are likely to be unbiased and objective, not only in their research work, but in other areas of their life as well.
- 20.2 Scientists will not be any more unbiased or objective in research work than many other Canadians are in their work.

- 20,3 Scientists will not be any more unbiased or objective in their daily living than many other Canadians.
- 21.1 There are justifiable reasons why so many Canadian scientists are male, rather than there being an equal proportion of male and female scientists.
- 21.2 There are no justifiable reasons why so many Canadian scientists are male, rather than there being an equal proportion of male and female scientists.
- 22.1 The qualities of honesty and objectivity, commonly associated with a scientific report, are largely due to the fact that scientists as a group tend to be more honest and objective than any other group of Canadians.
- 22.2 The qualities of honesty and objectivity, commonly associated with a scientific report, are largely due to the fact that other scientists might try to verify the report and could find embarrassing errors. Scientists as a group are no more honest and objective than any other group of Canadians.